DETECTION OF A MULTI-SEQUENCE SPREAD SPECTRUM SIGNAL

CROSS-REFERENCE TO RELATED PATENT

The subject matter of this application is related to the subject matter of U.S. Pat. No. 5,210,770 "Multiple-Signal Spread-Spectrum Transceiver" (hereinafter referred to as Rice '770), also by Bart F. Rice, the disclosure of which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to digital spread-spectrum communications and more particularly to a method and apparatus for detecting spreadspectrum signals employing multiple spreading sequences.

2. Description of Background Art

The field of wireless communications has been given a considerable impetus by Federal Communications Commission (FCC) Rule 15.247, which allows license-free operation of spread spectrum radios (subject to certain power restrictions) within the Industrial, Scientific, and Medical (ISM) bands: 902–928 MHz, 2400–2483.5 MHz, and 5725–5850 MHz. In response, several manufacturers have developed spread spectrum radios that operate in these bands (for example, Cylink, Omnipoint, Western Digital, Proxim, Win-Data). Spread spectrum communications and code division multiple access (CDMA) multiplexing are used in areas such as wireless communication, local area networks (LANs), personal communications networks (PCNs), and cellular telephone networks.

A conventional direct sequence spread spectrum signal can be viewed as the result of mixing a narrowband information-bearing signal i(t) with an informationless wideband (and constant envelope) "spreading" signal c(t). If B_i, B_c denote the bandwidths of i(t), c(t), respectively, then the "processing gain" available to the receiver is $G=B_c/B_i$, which can be realized (with some implementation losses, of course) by synchronizing the incoming signal to a locally generated version $c_O(t)$ of c(t), mixing the received signal and $c_O(t)$, thus removing c(t) from the signal and "collapsing" the signal to the "information bandwidth" B_i, within which the despread signal should have sufficient signal-to-noise ratio (SNR) to enable recovery of the information by standard means.

To increase the data rate in CDMA communication for a given chip rate and processing gain, multiple spreading sequences are used (see, for example, Rice, U.S. Pat. No. 5,210,770 "Multiple-Signal Spread-Spectrum Transceiver", and Vancraeynest, U.S. Pat. No. 5,063,571 "Method and Apparatus for Increasing the Data Rate for a Given Symbol Rate in a Spread Spectrum System"). By utilizing multiple periodic sequences, it is possible to increase the information rate with less loss in processing gain and concomitant increase in bit error rate than would result if the bandwidth B_i of the information signal were increased directly.

In a multiple sequence spread spectrum system, fixed lengths of each sequence are regarded as symbols that convey multiple bits of information. If the sequences are (nearly) "orthogonal" over the length of a symbol (their cross correlations are 0, or very nearly 0, compared to the sequence length), then they are the same distance apart regardless of their number. It is this fact that explains why using multiple sequences to increase data rate provides an improvement in performance over that obtained if the data rate is increased by simply increasing the bandwidth B_i of the information signal i(t), thereby directly decreasing the processing gain, G. In addition, a performance improvement in terms of capacity (number of users times data rate per user) is also realized by using multiple sequences in a spread spectrum code division multiple access (CDMA) network or a hybrid CDMA/FDMA/TDMA network.

When using multiple sequences it is important that the sequences not be merely time offsets of one another or else false synchronization could occur and symbols could be interpreted incorrectly (see, for example, Vancraeynest). One method that guarantees the independence of the spreading sequences at all offsets of one another is to add modulo-2 a pseudo-random sequence to whichever information-bearing sequence is to be transmitted. This approach also provides a large measure of flexibility in choosing data rates and processing gains (see, for example, Rice '770), and it enlarges the "code space" so that many users can be assigned unique spreading sequences.

A spread spectrum system that employs multiple sequences is the QUALCOMM CDMA system. In the QOUALCOMM system, the rows of a Hadamard matrix are used as spreading sequences. In one mode of operation, each row corresponds to multiple bits of information. The "chip sequence"(i.e., the bits that form the spreading-code sequence) is formed by combining (by modulo-2 addition) the bits of an independently generated sequence and a selected row of the Hadamard matrix, where the row corresponds to the information to be conveyed in the time required to transmit the bits in the given row (the "symbol interval"). This aspect of the QUALCOMM coding scheme is a slight variation of a Type 1 Reed-Muller code, a type of low-rate code that was employed in deep-space communications in the early days of the United States space program.

The QUALCOMM detection scheme first "strips"an "informationless" sequence from the received signal and then determines which row of the Hadamard matrix was transmitted by correlating the "stripped" signal with each row of the Hadamard matrix by computing a Fast Hadamard Transform (FHT), or Yates' Algorithm. The FHT on $N=2^n$ points is the most efficient of the Fast Fourier Transform (FFT) algorithms, as it requires no multiplications or divisions and only $N\times\log_2(N)$ adds/subtracts (real or complex as the input data is real or complex). The index of the transform coefficient with the largest magnitude indicates the transmitted row (according to the Maximum Likelihood decision rule).

In general, there is a need for a reliable and efficient technique for detecting spread-spectrum signals where the sender employs multiple spreading sequences for transmitting information (where the sequences are not rows of a Hadamard matrix). In addition, there is a need for a method for simultaneously correlating a received signal with all of the sequences possibly employed by the sender of a spread spectrum signal. Such a "block correlator" also requires an accurate method for carrier recovery and tracking, to bring the received signal to baseband. It is also advantageous to simultaneously accomplish carrier recovery, synchronization with the information bearing sequence, and synchronization with an error-correcting block code. Furthermore, there is a need for logic designs for hardware implementation of such processes and methods. The present invention addresses these needs and solves the problems presented.

DISCLOSURE OF INVENTION

The invention comprises a detector of a multiple-sequence spread spectrum signal. The received signal is first